Space Technology Research Grants

# Superconducting Nanowire Single Photon Detectors for High-Data-Rate Deep-Space Optical Communication

Completed Technology Project (2014 - 2018)

## Project Introduction

High data rate deep space optical communication (DSOC) links for manned and unmanned space exploration have been identified by NASA as a critical future capability, enabling advanced instruments, live high definition video feeds, tele-presence, and human exploration of Mars and beyond. Adopting optical communications promises a ten-to-one-hundred-times increase in data rates from deep space for equivalent spacecraft mass and power as compared to state-of-the-art deep-space Ka-band RF communication systems. One of the key enabling technologies for DSOC is a large area photon counting ground detector array. This array has been identified as a top priority in NASAs technology roadmap (as technology area 5.1.1). To minimize the resources consumed on the spacecraft, it is essential to have the best possible single photon counting detectors on the ground. Therefore, the ground detectors should be efficient (a large fraction of the incident photons should be registered as counts) with low jitter (indeterminacy in the photon arrival time), high maximum count rate, and low false count rate. Ground detector arrays capable of supporting Gb/s links from Mars and beyond are within reach, but still require further technological development. To address this need, the Space Technology Mission Directorate Game Changing Development program office has supported a DSOC technology development project at JPL to realize these goals using kilopixel arrays of tungsten silicide superconducting nanowire single photon detectors (WSi SNSPDs). To minimize the mass and power required on the spacecraft, future DSOC links will be encoded using pulse-position modulation (PPM). In PPM schemes, the maximum data rate achievable is ultimately limited by the timing jitter of the ground detector. While some NbN SNSPDs have demonstrated 25 ps jitter, they also have much lower detection efficiency and SNSPDs have not yet been developed which simultaneously achieve near-unity detection efficiency and 10s of picoseconds of jitter. Furthermore, we do not yet understand the fundamental limits to which the jitter of SNSPDs can be reduced. For my doctoral research at MIT, I will investigate the fundamental mechanisms of jitter in SNSPDs and engineer unity efficiency detectors with significantly reduced jitter. This will allow a dramatic increase in the fundamental data-rate limit in DSOC links. A key element of my project plan is numerical simulation coupled to nanoscale characterization. By creating more accurate models for SNSPD behavior and coupling these models to microscopic characterizations of actual nanowires I will be able to understand and then engineer jitter in these devices.

## Anticipated Benefits

High data rate deep space optical communication (DSOC) links for manned and unmanned space exploration have been identified by NASA as a critical future capability, enabling advanced instruments, live high definition video feeds, tele-presence, and human exploration of Mars and beyond. Adopting optical communications promises a ten-to-one-hundred-times increase in data


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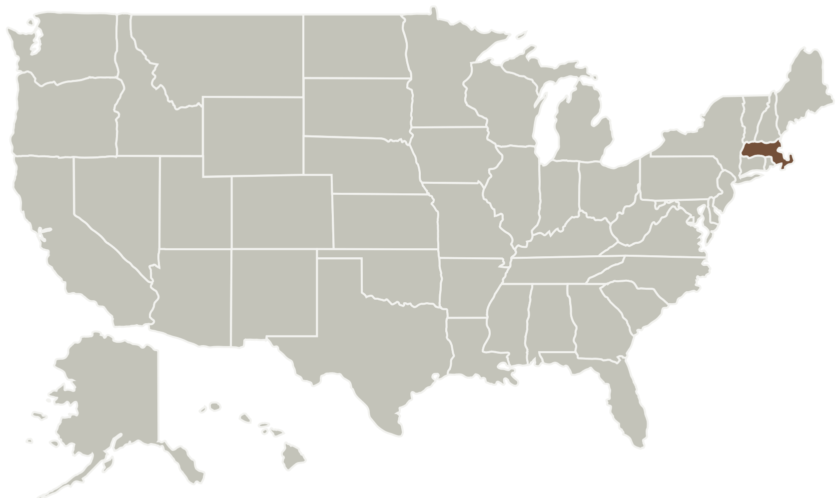
rates from deep space for equivalent spacecraft mass and power as compared to state-of-the-art deep-space Ka-band RF communication systems. This project investigates the fundamental mechanisms of jitter in superconducting nanowire single photon detectors and and design of unity efficiency detectors with significantly reduced jitter. This will allow a dramatic increase in the fundamental data-rate limit in DSOC links.

### Primary U.S. Work Locations and Key Partners



| Organizations Performing Work | Role | Type | Location |
|---|---|---|---|
| Massachusetts Institute of Technology(MIT) | Lead Organization | Academia | Cambridge, Massachusetts |

| Primary U.S. Work Locations |
|---|
| Massachusetts |

### Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

## Organizational Responsibility

**Responsible Mission Directorate:**

Space Technology Mission Directorate (STMD)

**Lead Organization:**

Massachusetts Institute of Technology (MIT)

**Responsible Program:**

Space Technology Research Grants

## Project Management

**Program Director:**

Claudia M Meyer

**Program Manager:**

Hung D Nguyen

**Principal Investigator:**

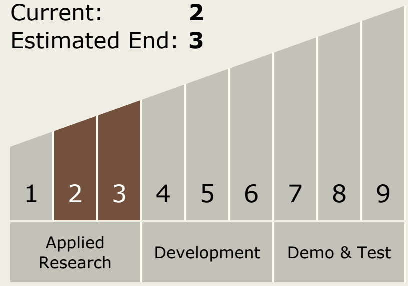
Karl Berggren

**Co-Investigator:**

Andrew Dane

## Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**




## Technology Areas

**Primary:**

- TX05 Communications, Navigation, and Orbital Debris Tracking and Characterization Systems
  └ TX05.1 Optical Communications
    └ TX05.1.1 Detector Development

## Target Destinations

Mars, Others Inside the Solar System